



Shallow geothermal technology as alternative to diesel heating of subarctic off-grid autochthonous communities in Northern Quebec (Canada)

Nicolò Giordano¹, Evelyn Gunawan^{1,2}, Félix-Antoine Comeau¹, Mafalda Miranda¹, Hubert Langevin¹, Matteo Covelli³, Paul Piché⁴, Jessica Chicco³, Stéphane Gibout⁴, Didier Haillot⁵, Alessandro Casasso⁶, Giuseppe Mandrone³, Cesare Comina³, Richard Fortier⁷, and Jasmin Raymond¹

¹Centre Eau Terre Environnement, Institut national de la recherche scientifique, Québec, Canada
(nicolo.giordano@ete.inrs.ca)

²Iceland School of Energy, Reykjavik University, Reykjavik, Iceland

³Università degli Studi di Torino, Dipartimento di Scienze della Terra, Torino, Italia

⁴Université de Pau et des Pays de l'Adour, Laboratoire de Thermique, énergétique et procédés, Pau, France

⁵École de Technologie Supérieure, Département de génie mécanique, Montréal, Canada

⁶Politecnico di Torino, Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture, Torino, Italia

⁷Université Laval, Département de géologie et génie géologique, Québec, Canada

In the north of Québec (Canada), off-grid aboriginal communities rely on diesel for both space heating and electricity production. Renewable alternatives are therefore necessary to reduce the impact of burning diesel in a region with strong population growth and increasing energy needs. The main challenges are the subarctic environment (more than 8000 heating degree days), the presence of permafrost and the lack of local expertise on drilling and installation of borehole heat exchangers.

The communities of Kuujuaq (58 °N) and Whapmagoostui-Kuujuarapik (W-K, 55 °N) were chosen as case studies to evaluate the shallow geothermal potential and predict the long-term behaviour of ground source heat pumps (GSHP) and underground thermal energy storage systems (UTES). Local geology mainly consists of low permeable and thermally conductive crystalline bedrock (thermal conductivity of 2-4 W/mK) underlying highly permeable, frost-susceptible and poorly conductive marine sediments (thermal conductivity of 1-1.5 W/mK), generally not thicker than 30-40 m. Electrical resistivity tomography and ground penetrating radar surveys have been carried out to locally evaluate the presence of ice-rich ground that strongly depends on the local hydrogeological conditions. Average underground temperature in the first 100 m is around 1 °C in Kuujuaq and 2 °C in W-K. Geothermal gradient and heat flux were estimated to be on average 15 °C/km and 40 mW/m², respectively.

Results of the studies carried out in these villages show that both GSHP and UTES are viable technologies to replace part of the current diesel consumption of residential buildings and

drinking water facilities, with 10% to 50% primary energy saving depending on the technology. Fifty years' life-cycle cost analyses demonstrated that the levelized cost of energy for GSHP and UTES is as low as 0.10 and 0.19 USD\$/kWh, respectively, compared to the business-as-usual scenario standing at 0.21 USD\$/kWh. It also turned out that the energy and drilling costs are key obstacles to a widespread deployment of these technologies in the North. A cost of 110 USD\$/m has been defined as a threshold for getting interesting paybacks on the initial financial investment. UTES is also a valuable technology aiming to extend the growing season of community greenhouses in place in both Kuujuaq and W-K. In Kuujuaq, a coupled daily and seasonal heat storage is under study to provide renewable heat and help increase the food security in Nunavik.

Future activities aim at the set-up of a first demonstration plant to be tested in a subarctic environment with underground close to permafrost conditions. A 200-m well will be drilled in 2020 in W-K and the installation of a borehole heat exchanger will be showcased for technological transfer. Conventional thermal response tests (TRT) and a novel approach of oscillatory TRT will also be carried out to evaluate the in-situ thermal conductivity and heat capacity.